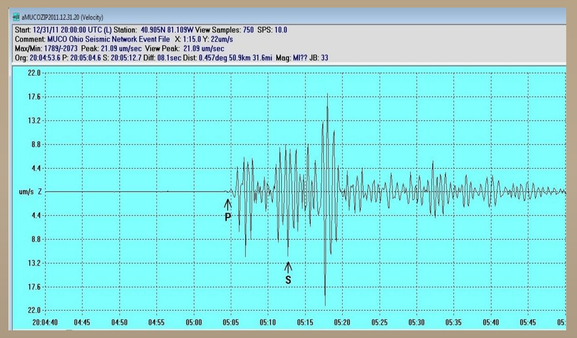
Insights on Induced Seismicity in Ohio from the Youngstown M4.0 Earthquake

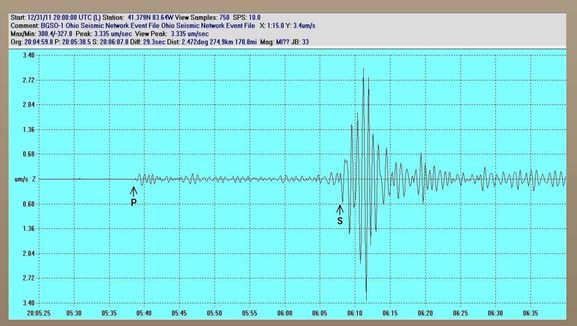
Jacqueline Mills

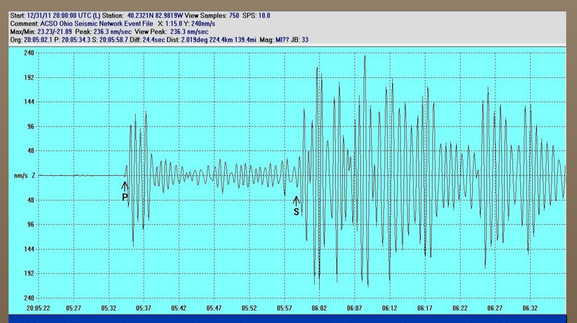
SCHOOL OF EARTHSCIENCES

1. Background

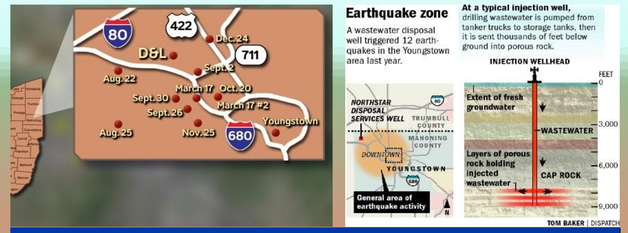
Hydraulic fracturing, also known as fracking, is the process in which a solution, consisting of sediments and chemicals, is injected below the crustal surface at high pressures to break up rock and enhance natural gas and oil production. This process produces brine waste water, which is then injected deep into the earth's crust for disposal. There are currently 10 active injection wells in Ohio. The Northstar 1 deep injection well in Youngstown, Ohio became operational in January 2011 and just three months later in March 2011, the first induced earthquakes occurred. After the 10th earthquake in a matter of months, the well was voluntarily shut down. The shutdown was followed days later with a magnitude 4.0 earthquake on December 31, 2011.



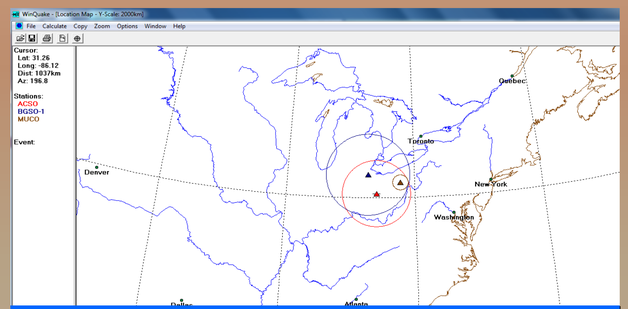




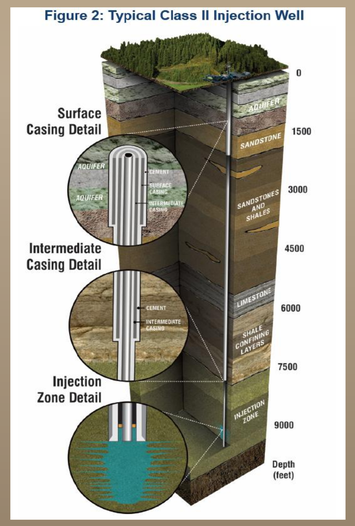
(Above) These charts are called seismograms. The P waves (compressional body wave) and S waves (shear surface wave) are labeled on each. Between these three stations we can determine where an epicenter is located.



(Top Left) This is a map displaying epicenters from the time of the Northstar 1 injection well going operational to the time it was shut down, with the dates labeled beside each epicenter point. (Top Right) This is a diagram of a typical injection well, also with another diagram displaying the general location of the earthquake activity and the injection well.

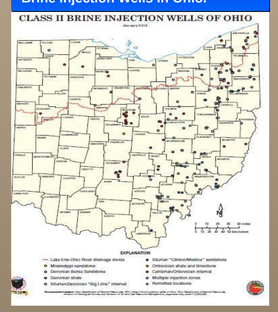


(Above) Using the information from each of the station's seismograms (Bottom Left), This location map indicates where the epicenter is located by where the three intersect.



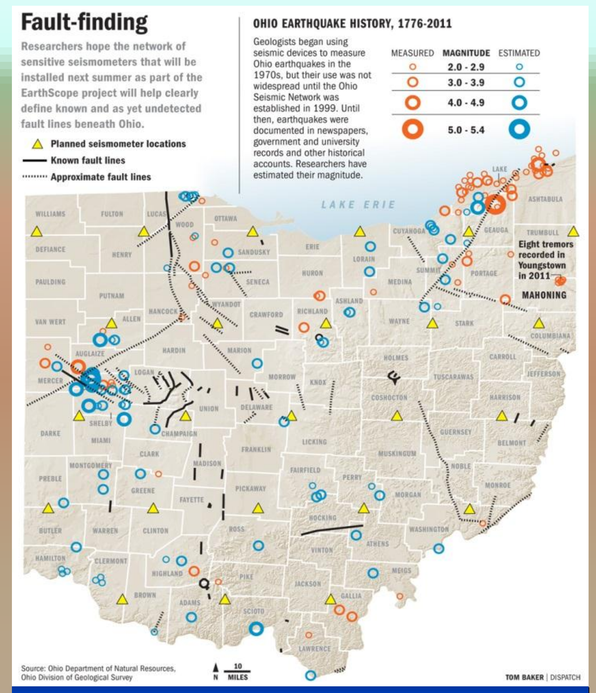
(Left) This is a diagram of a typical Class II Injection Well. As you can see, it breaks down how the system is constructed through some of the major layers, including our aquifer, the shale layers, and the injection zone. Along the right side of the diagram you can see that it is also measured in feet.

(Below) This is a map of the Class II Brine Injection Wells in Ohio.



2. Objective

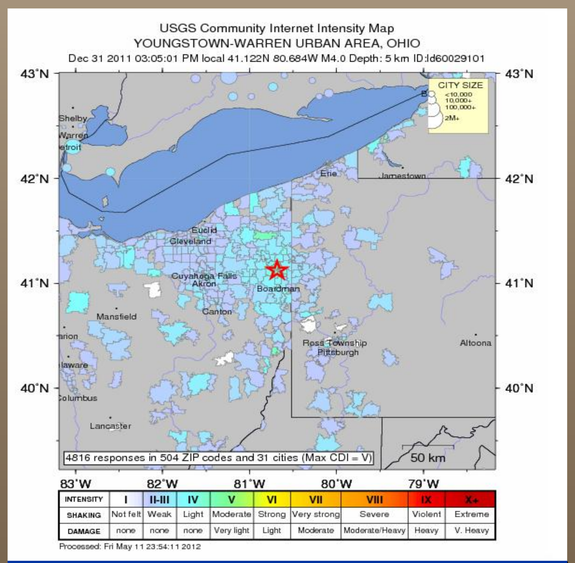
Researching the correlation between deep well injections and the intensities and frequencies of earthquakes can help us better understand not only how but where the ground is fracturing. This research will also help us better understand where unidentified faults are located and how to more easily identify them prior to drilling the injection wells. By bringing attention to these faults, we can avoid placing deep injection wells around them to limit induced seismicity. This can also help us learn how to better utilize the Ohio's subsurface for deep well injection and storage.



(Above) This is a fault map of Ohio. This map will be able to help us understand where possible hazard areas would be, such as in the cases of waste water injection.

3. Research Methods

Research was completed through studying Ohio's geological history, the stratigraphy of eastern Ohio, and articles collected from newspapers and the scientific literature on the geology of Youngstown and its utility for deep well injection and storage.



(Above) This is an intensity map. This displays the reported intensity of the 4.0 Youngstown earthquake felt by people, and the areas that were affected by the earthquake. Based on the Modified Mercalli Scale.

4. Conclusions

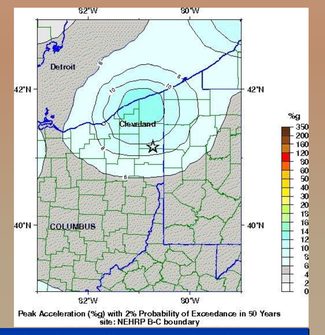
The Youngstown M4.0 earthquake of December 31, 2011 resulted from the injection of waste water produced by fracking. Despite public opinion that views fracking as the main cause of the enhanced seismicity in the Youngstown area, the real culprit appears to have been the disposal of the waste water under pressure.

Selected Cities Exposed

from GeoNames Database of Cities with 1,000 or more residents.

MMI	City	Population
IV	Mineral Ridge	4k
IV	Boardman	36k
IV	Churchill	3k
IV	Youngstown	78k
IV	Girard	10k
IV	McDonald	3k
I	Cleveland	450k
I	Pittsburgh	319k
I	Akron	208k
I	Erie	100k
I	Parma	83k

(k = x 1,000)



(Top left) This is a population table based on the Modified Mercalli Scale indicating the level of intensity each of the cities experienced for the M4.0. (Top Right) This is a seismic hazard map conducted by USGS for the M4.0.

Acknowledgements

I would like to thank Shell for this Summer Undergraduate Research Experience. I would also like to thank my advisor Dr. Ralph R.B. von Frese, Mary Scott, PhD student Jameson Scott and Dr. Anne Carey for their help and guidance on this project, Also to Dr. Mike Hansen and Dr. Tim Leftwich of the OhioSeis Network, Division of Geological Survey, Ohio Department of Natural Resources.

References

Fountain, Henry. (January 1st, 2012). *Disposal Halted at Well After New Quake in Ohio.* The New York Times. Retrieved from: http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html?_r=1.

Funk, John. (March 9th, 2012). *Waste-Water Injection Well Caused 12 Earthquakes in Ohio, Investigation Shows.* The Plain Dealer, Cleveland.com. Retrieved from:http://www.cleveland.com/business/index.ssf/2012/03/shale_gas_drilling_caused_smal.html.

Funk, John. (June 15th, 2012). *Fracking Fluid Injection Wells Can Cause Quakes, Study Finds.* The Plain Dealer, Cleveland.com. Retrieved from: http://www.cleveland.com/business/index.ssf/2012/06/fracking_fluid_injection_wells.html.

Ohio Department of Natural Resources, ODNR. (March 2012). *Preliminary Report On the Northstar 1 Class II Injection Well and the Seismic Events in the Youngstown, Ohio Area.* Retrieved from: http://ohiodnr.com/downloads/northstar/UICreport.pdf.

The Ohio Seismic Network, Ohio Seis: http://www.dnr.state.oh.us/tabid/8144/Default.aspx

US Geological Survey, USGS: http://www.usgs.gov/